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Technology Development of Fabrication Techniques for Advanced Solar Dynamic Concentrators

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TECHNOLOGY DEVELOPMENT OF FABRICATION TECHNIQUES FOR ADVANCED SOLAR DYNAMIC CONCENTRATORS

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ABSTRACT

In 1985, the NASA Lewis Research Center initiated the Advanced Solar Dynamic Concentrator Technology Development Program as part of an overall Advanced Solar Dynamic Power System Project. The objective of the Advanced Concentrator Program is to develop the technology that will lead to lightweight, highly reflective, accurate, scaleable and long-lived space solar dynamic concentrators.

The Advanced Concentrator program encompasses new and innovative concepts, fabrication techniques, materials selection, and simulated space environmental testing. Fabrication techniques include methods of fabricating the substrates and coating substrate surfaces to produce high quality optical surfaces, acceptable for further coating with vapor deposited optical films.

The selected materials to obtain a high quality optical surface include microsheet glass and Eccocoat EP-3 epoxy, with DC-93-500 selected as a candidate silicone adhesive and leveling layer. The following procedures are defined; cutting, cleaning, forming, and bonding microsheet glass. Procedures are also defined for surface cleaning, and EP-3 epoxy application. The results and analyses from atomic oxygen and thermal cycling tests will be used to determine the effects of orbital conditions in a space environment.

1.0 INTRODUCTION

The concentrator is a reflector that is configured to collect the Sun's energy and focus it into a receiver which heats the working fluid of a power conversion system, i.e. Brayton or Stirling engine. The concentrator is a key technology of a solar dynamic power system. Advanced Solar Dynamic Power systems for applications beyond the Space Station are being investigated at NASA Lewis. In 1985, the

NASA Lewis Research Center initiated the Advanced Solar Dynamic (ASD) Concentrator Program. The objectives of the ASD concentrator program are to develop the technology that will lead to lightweight, highly reflective, accurate, scaleable and long lived (10 years) solar dynamic concentrators. The long term goals identified for the program include a concentration ratio greater than 2000:1, a reflectance greater than 90%, surface accuracies of 0.5 to 1.5 mrad, and a specific weight less than 1.5 kg/m². In addition to the technical challenge of designing a solar concentrator to meet these goals, the concentrator must resist the effects of the space environment. Environmental effects include orbital sun/shade thermal cycling, atomic oxygen erosion, ultra violet radiation, space debris, micrometeoroid impact, and plasma arcing. The ASD concentrator program is addressing the effects of two critical environmental factors including thermal cycling and atomic oxygen. The orbital sun/shade thermal cycling may cause surface delamination of concentrator films due to coefficient of thermal expansion (CTE) mismatching between layers. Atomic oxygen (AO) is a very energetic form of oxygen found in low earth orbits. AO reacts with many organic and inorganic materials to cause a reduction in mass and thus reducing the integrity of the material.

To develop a concentrator to meet the design and environmental goals of the ASD Concentrator program, material selection is critical. The components of a concentrator panel include a substrate to provide mechanical support and stability, a very smooth leveling layer to provide a base on which a highly reflective coating is deposited, and finally a protective coating.

The ASD Concentrator program has identified two leveling layer concepts including microsheet glass and polymer coatings to produce a mirror like, high quality optical surface. In both concepts aluminum

was chosen as the substrate, and a thin vapor deposited film of aluminum for the reflective layer.

Test coupons have been fabricated at NASA Lewis for an EOIM-III STS-46 space shuttle flight test to evaluate materials compatibility with AO (Fig 1.0).



Microsheet Glass

Eccocoat EP-3 Coating

Figure 1.0 - Shuttle flight coupons

There are four sets of four coupons each, for a total of sixteen coupons. The highest quality coupon from each group will fly, while the remaining twelve will be used for reference and testing. All sixteen coupons are 1 in. diameter, 0.1 in. thick 6061-T6 aluminum machined to a 32 rms surface on one side. Applied to the first set of four coupons was a 0.001 in. thick coating of Emerson and Cumings Inc. EP-3 epoxy. An 800 Angstroms thick reflective coating of aluminum and a protective coating of SiOx was also applied. The second set of coupons are identical with the only exception being that 1500 Angstroms of aluminum was deposited compared to 800 Angstroms. The third and fourth sets of coupons were fabricated by bonding 0.006 in. microsheet glass to aluminum using Dow Corning's DC-93-500 adhesive. An 800 Angstrom thick reflective coating of aluminum was applied to both the third and fourth set of coupons and a protective coating of SiOx was applied only to the third set. The flight coupons are to test the environmental effects of atomic oxygen on two levelizing concepts; microsheet glass and EP-3 polymer. The flight test will be used to assess the effect of reflective coating thickness, and the benefits of a protective coating.

Fabrication techniques for developing concentrator panels have been identified as part of the ASD Concentrator program through an in-house effort at NASA Lewis.

2.0 MICROSHEET GLASS LEVELIZING

Microsheet glass is an excellent candidate as a levelizing layer to provide an optical surface for solar concentrators because of its outstanding optical properties and its ability to resist atomic oxygen corrosion.[1] Microsheet glass is the name given to a family of soda lime glasses ranging in thickness from 1 to 20 mil; it is available in widths of 14 in., by virtue of its forming process, and indefinite lengths. Glass is used in many of the terrestrial solar concentrator applications to provide a high quality optical surface for the reflective film (i.e. aluminum). The application can be for a first surface or second surface mirror.

There are several technical challenges to be overcome in the fabrication a microsheet glass concentrator panel. These challenges include cutting, cleaning, forming and bonding the microsheet glass.

2.1 Microsheet Glass

The panel size of a microsheet glass concentrator is limited by the size of a microsheet glass sheet. To date, Corning Glass Inc. manufactures sheets limited to a 14 in. width with indefinite, longer lengths. The process is not limited to size, but only to the present production equipment, which can potentially be increased to accommodate larger widths. A procedure was developed at NASA Lewis to cut the glass to a specified panel size, including curved or straight cuts.

I. GLASS CUTTING PROCEDURE

- 1.0 Secure glass segment on flat surface via vacuum chuck
- 2.0 Oil tip of diamond tip scribe
- 3.0 Follow contour of template applying a slight pressure (5 psi) and holding scribe at a 75 degree angle
- 4.0 Flex glass away from face by holding glass firmly on each side of the scribe line
- 5.0 Heat treat cut edge with a propane burner

It is critical for the glass to be clean prior to vapor deposition of a reflective coating. Dust, oil, fingerprints etc. will greatly reduce the overall

reflectivity of the panel. Improper cleaning of the glass reduces the bonding strength between the aluminum substrate and the microsheet glass. The following procedure was developed:

II. GLASS CLEANING PROCEDURE

- 1.0 Remove grease, oil, etc. by vapor degreasing or solvent cleaning
- 2.0 Immerse 8 to 12 min. in an ultrasonic cleaner with a solution of Micro lab cleaner
- 3.0 Rinse thoroughly in deionized water so the final pH will be between 5.0 and 8.5
- 4.0 Air or oven-dry sample at temperatures up to 150°F
- 5.0 Perform a water break test - If the water breaks, repeat steps 1-5
- 6.0 Apply a thin coat of Chemlock AP 134 to prep the glass for bonding by flow coating

Notes:

- 1) Step 6 is to be administered after heat forming
- 2) Store sample in a clean, dry atmosphere up to 6 hours prior to bonding

One of the most challenging efforts in fabricating a microsheet glass concentrator is the forming of the thin glass to a contoured shape (i.e. parabolic). NASA Lewis developed a procedure (procedure III) using a machined graphite mold, Pyrex glass and a vacuum furnace to heat form (slump) glass from flat microsheet glass into a desired contour. Initially a sheet of Pyrex glass with a thickness of 0.25 in. is slumped to conform to a graphite mold. The Pyrex sheet is used as a glass master on which to slump the microsheet glass. It should be noted that the surface of the Pyrex glass will be the final contour of the parabola and that the graphite mold will be machined to compensate for the 0.25 in. thickness of the Pyrex (Fig 2.0). This approach evolved from an initial approach where the microsheet glass was formed directly on the graphite mold. It was found that the surface imperfections which existed in the graphite surface were transferred to the microsheet glass.[1] To date a 4 in. wide x 6 in. long x 0.004 in. thick microsheet glass sample has been slumped successfully at NASA Lewis.

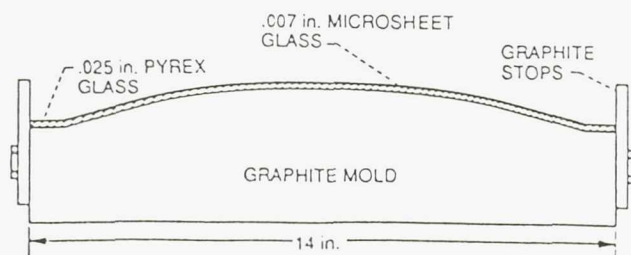


Figure 2.0 - Glass forming mold

III. MICROSHEET GLASS FORMING PROCEDURE

- 1.0 Place 0.25 in. thick pyrex glass precut on top of machined graphite mold
- 2.0 Place mold with pyrex glass in an Argon back fill vacuum furnace
- 3.0 Heat Furnace at a rate of 10°F/min. to a temperature just below the softening point (1221°F) - hold at softening point for 30 min.
- 4.0 The glass is then cooled to a temperature just above the annealing point (990°F) at a rate of 10°F/min., and held for 1 hour
- 5.0 The glass is then cooled at a rate of 3°F/min. to a temperature just below the strain point 923°F
- 6.0 Power is then turned off, and the glass is cooled to room temperature
- 7.0 The 0.004 in. microsheet glass is placed on top of the 0.25 in. pyrex and glass mold
- 8.0 The microsheet glass will slump to conform to the pyrex surface (graphite surface is porous)
- 9.0 Steps 2-6 are repeated for the microsheet glass noting the critical temperatures for microsheet glass:

Working point	= 1847°F
Softening point	= 1328°F
Annealing point	= 1022°F
Strain point	= 941°F

Note: The differential in C.T.E. will prevent the glasses from fusing together

2.2 Substrate

The substrate is a critical element of a solar concentrator. The substrate must be smooth, rigid, space survivable and have a low mass per support area for reflective surfaces. One of the most degrading effects is atomic oxygen (AO). AO can penetrate and affect the substrate through surface microscopic imperfections, porosity of the protective coating, in the reflective coating, and through the edges of the concentrator panel. Measures can be taken to protect the panel from AO attack, although finding a substrate that minimizes AO attack.

Aluminum was selected as a substrate material because of its light weight, availability, low cost, structural properties, resistance to AO attack, and extensive database. Mechanical polishing or diamond tip machining of aluminum is costly and precludes the application of large concentrator panels.

A two meter diameter prototype solar concentrator has been designed by CSU/AMC NASA grant #NAG-3-77 as part of the ASD Concentrator effort to demonstrate the level of technology required for

future space applications.[2] The concentrator consists of a 0.235 in. aluminum honeycomb, sandwiched between a 0.003 in. thick backsheet and a 0.012 in. thick facesheet. A surface leveling coating can be applied to the surface of this substrate in the form of microsheet glass or polymer coating.

2.3 Adhesive

The selected adhesive to bond microsheet glass to an aluminum substrate is Dow Corning's space grade, low viscosity DC 93-500. DC 93-500 was the adhesive selected to bond the coverglass to photovoltaic arrays for Space Station Freedom. When DC 93-500 is exposed to AO, a thin film of SiO_2 will form on the surface, acting as an AO barrier.

DC 93-500 is a space qualified adhesive that meets NASA flight specifications (i.e. outgas). Upon curing, DC 93-500 is very elastic and acts as a mechanical buffer between the glass and aluminum differential CTE's.

2.4 Bonding Procedure

Procedure IV was developed at NASA Lewis to fabricate a microsheet glass panel. To date a 12 in. square panel was fabricated at NASA Lewis using 0.004 in. microsheet glass bonded to a 0.0625 in. mill finished aluminum substrate. The glass surface was aluminized. The measured reflectance was over 91% and a surface error was estimated to be 0.8 mrad.

2.5 Reflective Layer

A reflective, thin film layer of aluminum will be deposited to the front face of the concentrator panel at a thickness of 1200 Angstroms. Aluminum was chosen over silver even though the solar-weighted reflectance of aluminum is lower than silver, because aluminum resists abrasion better and can react with air to form passive oxide films.[3]

A protective coating will be deposited on the reflective aluminum coating. These protective coatings include several transparent dielectric thin films, including MgF_2 , Al_2O_3 and SiO_x . These protective coatings offer surface abrasion protection for handling and also offer atomic oxygen

protection. Although metal oxides offer protection against atomic oxygen, atomic oxygen undercutting at inherent defect sites can be a problem for the panels life.[4] For this reason, microsheet glass provides an atomic oxygen barrier between the substrate and protective coating, offering additional protection for the panel.

IV. MICROSHEET GLASS BONDING PROCEDURE

- 1.0 Follow procedures I,II,III, and IV to prepare the substrate and glass
- 2.0 Prepare DC 93-500 low viscosity grade encapsulant
 - 2.1 Add 10:1 parts by weight resin to hardener
 - 2.2 Add hardener slowly to resin
 - 2.3 Agitate using air-powered propeller-type mixer for 10 minutes
- 3.0 Atomizing spray gun (Binks type 2001 gun)
 - 3.1 Pour DC 93-500 through 600 stainless mesh into spraygun cup
 - 3.2 Pressurize gun to 20 psi
 - 3.3 Allow mixture to stand for 10 minutes
 - 3.4 Apply coating to aluminum panel
 - 3.4.1 Nozzle distance is 14 in. from panel
 - 3.4.2 Spray pattern is 8 in. wide
 - 3.4.3 Coat panel twice using overlapping spray patterns
 - 3.4.4 Apply a 0.001 in. thick coat
- 4.0 Apply microsheet glass
 - 4.1 Place glass edge on top of panel
 - 4.2 Slowly ease glass downward increasing contacted surface area
 - 4.3 Force any air entrapment outward
- 5.0 Cure samples
 - 5.1 1 hour at room temperature
 - 5.2 2 hours at 150°F
 - 5.3 3 hours at 250°F
 - 5.4 1 hour at 275°F

3.0 POLYMER LEVELING COATING

A second approach to obtaining a high quality optical surface is the application of a very smooth leveling polymer coating. The application of surface leveling coatings followed by aluminum deposition has been successfully used in the fabrication of extremely smooth surfaces required for x-ray telescopes.[5] EP-3 has been identified as an excellent candidate for surface leveling, and is a two part epoxy manufactured at Emerson & Cumings Inc. EP-3 has not been qualified for space application, but can be used to prove coating application techniques. The coating procedures may be adapted for other space qualified materials (i.e. DC 93-500). The amount of coating to be applied

is determined by the depth of the surface irregularities.[6] For mill finished aluminum, a 0.001" thick coating of EP-3 was determined to be sufficient to effectively cover the surface irregularities.

3.1 Substrate

The objective in the surface preparation of aluminum is the chemical cleaning of metal and to remove organic and inorganic surface impurities to provide good wetting and bonding of leveling coating. A chemical cleaning procedure was developed by NASA Lewis. Table I lists the results of 29 test sequences needed to produce the best epoxy wetting of the surface for chemical cleaning of aluminum.

	TEST SEQUENCE	CLEANING AGENT	TEMPERATURE °C	IMMERSION TIME	RESULTS
SOLVENT CLEAN	1A	METHYL ETHYL KETONE	22.0	30 SEC	POOR WETTING
	1B	METHYL ISOBUTYL KETONE	22.0	30 SEC	POOR WETTING
	1C	TOLUENE	22.0	30 SEC	POOR WETTING
	1D	ISOPROPYL ALCOHOL	22.0	30 SEC	POOR WETTING
ALKALINE CLEAN	2A	OAKITE 61B	80.0	20 MIN	POOR WETTING
	2B	BORAX	80.0	8 MIN	POOR WETTING
ACID CLEAN	3	PASA JELL 105	22.0	30 MIN	POOR WETTING
SOLVENT & ALKALINE CLEAN	4A	SEQUENCE 1A, FOLLOWED BY 2A			POOR WETTING
	4B	SEQUENCE 1A, FOLLOWED BY 2B			POOR WETTING
	4C	SEQUENCE 1B, FOLLOWED BY 2A			POOR WETTING
	4D	SEQUENCE 1B, FOLLOWED BY 2B			POOR WETTING
	4E	SEQUENCE 1C, FOLLOWED BY 2A			POOR WETTING
	4F	SEQUENCE 1C, FOLLOWED BY 2B			POOR WETTING
	4G	SEQUENCE 1D, FOLLOWED BY 2A			POOR WETTING
	4H	SEQUENCE 1D, FOLLOWED BY 2B			POOR WETTING
ALKALINE & ACID CLEAN	5A	SEQUENCE 2A, FOLLOWED BY 3			POOR WETTING
	5B	SEQUENCE 2B, FOLLOWED BY 3			POOR WETTING
SOLVENT & ACID CLEAN	6A	SEQUENCE 1A, FOLLOWED BY 3			POOR WETTING
	6B	SEQUENCE 1B, FOLLOWED BY 3			POOR WETTING
	6C	SEQUENCE 1C, FOLLOWED BY 3			POOR WETTING
	6D	SEQUENCE 1D, FOLLOWED BY 3			POOR WETTING
SOLVENT & ALKALINE & ACID CLEAN	7A	SEQUENCE 1A, FOLLOWED BY 2A, FOLLOWED BY 3			SPOTTY WETTING
	7B	SEQUENCE 1A, FOLLOWED BY 2B, FOLLOWED BY 3			SPOTTY WETTING
	7C	SEQUENCE 1B, FOLLOWED BY 2A, FOLLOWED BY 3			SPOTTY WETTING
	7D	SEQUENCE 1B, FOLLOWED BY 2B, FOLLOWED BY 3			SPOTTY WETTING
	7E	SEQUENCE 1C, FOLLOWED BY 2A, FOLLOWED BY 3			GOOD WETTING
	7F	SEQUENCE 1C, FOLLOWED BY 2B, FOLLOWED BY 3			SPOTTY WETTING
	7G	SEQUENCE 1D, FOLLOWED BY 2A, FOLLOWED BY 3			SPOTTY WETTING
	7H	SEQUENCE 1D, FOLLOWED BY 2B, FOLLOWED BY 3			SPOTTY WETTING

Table 1 - Chemical cleaning trials

The cleaning test matrix described in table I was based on the following chemical cleaning processes, and combinations of each.

- 1.0 Solvent vapor degreasing - removal of unsaponifiable mineral oils and greases
- 2.0 Hot-alkaline immersion cleaning - removal of organic and water soluble oils, vegetable and animal greases, and dirt by detergent action and saponification

- 3.0 Acid immersion cleaning - removal of surface oxide and scale from metal surface.[8]

Procedure V describes in detail the selected cleaning procedure:

V. CLEANING PROCEDURE FOR ALUMINUM

- 1.0 Use 600 grit wet/dry sandpaper to wet sand surface of aluminum in a figure eight motion
- 2.0 Immerse in bath of toluene to remove residue
- 3.0 Vapor degrease sample for 10 min using Trichloroethane heated to 160 F, use wand to rinse sample
- 4.0 Rinse with deionized water at room temperature
- 5.0 Place in bath of alkaline cleaner, Oakite 61B, maintain pH of 5 - 8.5 at 140°F
- 6.0 Rinse with deionized water at 150 F
- 7.0 Apply liberal coating of Pasa Jell 105 at room temperature for 30 min
- 8.0 Flush thoroughly with deionized water at 170 F for 2 minutes
- 9.0 Perform a water break test, if water breaks repeat steps 3-9
- 10.0 Flush sample with clean argon, store oven or air dry up to 6 hours prior to coating



3.1 Improper cleaning



3.2 Solid Impurity protruding through epoxy surface



3.3 Localized non-wetting



3.4 Solid impurity under epoxy surface

Figure 3.0 - Common surface defects

Common surface irregularities found on coated samples are shown in figure 3.0. The defects are magnified 300 times. Figure 3.1 illustrates a defect due to improper cleaning. Figure 3.2 exhibits a solid impurity protruding through the surface of the epoxy. Figure 3.3 demonstrates localized nonwetting due to improper cleaning, and figure 3.4 shows a solid impurity located under the epoxy surface.

3.2 Coating Application

The application of the Eccocoat EP-3 takes place in a clean chamber that filters particles down to 0.4 microns in diameter. This environment is critical to apply a coating with minimal surface imperfections (Fig. 4.0). Procedure VI was developed to coat mill finished panels with Eccocoat EP-3 Epoxy.

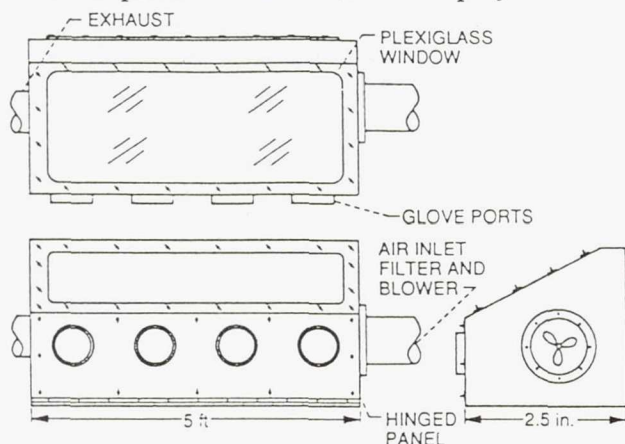


Figure 4.0 - Clean Chamber

VI. ECCOCOAT EP-3 COATING PROCEDURE

- 1.0 Mixing Ratio - 2 parts resin to 1 part hardener by weight
- 2.0 Pour resin through 600 mesh stainless screen, agitate for 10 minutes
- 3.0 Slowly add hardener through screen to a well stirred resin
- 4.0 Agitation by means of an air-powered propeller-type mixer for 15 minutes
- 5.0 Completely mixed epoxy has a pot life of 6 hours, and a shelf life of 6 months
- 6.0 Addition of solvents
 - 6.1 Selected solvents
 - 6.1.1 Toluene - 40 percent by weight
 - 6.1.2 Methyl Isobutyl Ketone - 60 percent by weight
 - 6.2 Solvent/Epoxy ratio = 5/95 percent by weight
 - 6.3 Benefits of solvents
 - 6.3.1 Reduction in viscosity
 - 6.3.2 Improved leveling
 - 6.3.3 Improved covering
 - 6.3.4 Delay resin hardener reaction
- 7.0 Mixing solvents and epoxy
 - 7.1 Completely agitate resin/hardener mixture
 - 7.2 Pre-measure solvents
 - 7.3 Add Toluene
 - 7.4 Add MIBK
- 8.0 Atomizing spray gun (Binks type 2001 gun) - Same as section 3.0 in procedure V

Notes:

- 1) All steps should take place under clean conditions
- 2) Add solvents just prior to spraying

3.3 Curing Schedule

The selected polymer coating Eccocoat EP-3, consists of an epoxy resin and an aliphatic amine hardener, which are mixed just prior to use. The characteristics of the sprayed film are determined by the coating formulation and by the resin/hardener reaction rate. Organic solvents are added to the epoxy mixture to reduce the viscosity and to improve covering and leveling.[7] A coating with excellent leveling, and wetting characteristics was obtained by adding 5 weight per-cent solvent to 95 weight percent Eccocoat EP-3. The solvent breakdown was 60 weight percent methyl isobutyl ketone and 40 weight percent toluene.[7] An epoxy resin cures or hardens by a chemical reaction between the epoxy groups in the resin and other groups provided by the hardening agent used. A typical example using an amine hardener illustrates the process:



Note that the remaining hydrogen on the amine group can react with another epoxy group to form a three-dimensional, cross-linked structure that has inherently strong bond strength. The epoxy resin-hardener reaction will not go to completion in the desired manner in any reasonable time without the application of heat.[7,8] The curing cycle is initiated as soon as the resin and hardener is mixed, while the addition of solvent retards the reaction rate. The curing takes place in a automated, programmable curing rig (Fig 5.0).

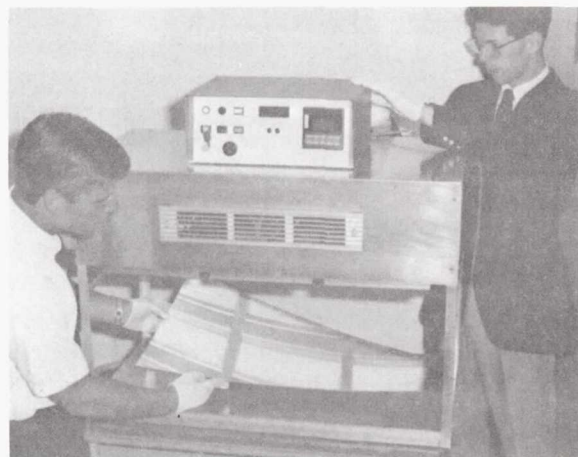


Figure 5.0 - Automated curing rig

Up to 40 temperature set points can be programmed into the controller corresponding to a time interval (Fig. 5.0).

The most effective curing procedure for EP-3 described in table II.[7]

CURING TIME (hr)	CURING TEMPERATURE	
	° C	° F
1.0	22.2	72.0
1.0	29.4	85.0
0.5	35.0	95.0
0.5	40.6	105.0
0.5	51.7	125.0
0.5	60.0	140.0
1.0	68.3	155.0
1.0	79.4	175.0
2.0	85.0	185.0

Table 2 - EP-3 curing schedule

4.0 EVALUATION OF COATINGS

An automated, programmable thermal cycling rig was designed and fabricated at NASA Lewis to test the effects of orbital sun/shade cycles (figure 6.0). Various temperature/time profiles, depending on the orbital parameters, can be programmed using a controller. A 1.0 in. diameter, 0.1 in. thick aluminum sample with 0.004 in. of microsheet glass bonded via DC 93-500 was tested at NASA Lewis. The coupon was coated with 1200 Angstroms of aluminum. The coupon survived over 500 cycles between a temperature range of -80°C to 80°C, with no obvious degradation.

Similarly, a 4 in. square, 0.0625 in. thick aluminum sample coated with 0.001 in. thick Eccocoat EP-3 polymer, and a 1200 Angstrom thick coating of aluminum survived over 20 cycles with temperatures of -195°C to 100°C with no apparent degradation.

Future ASD concentrator efforts include testing concentrator elements in AO environment (i.e. A.O. asher), testing elements for micrometeoroid impact, and analyzing flight coupons from shuttle flight EOIM-III STS-46.

5.0 CONCLUDING REMARKS

Procedures have been defined to successfully cut, clean and bond microsheet glass to an aluminum

substrate to produce a high quality, optical surface. This concept holds a great deal of promise for future space applications. A microsheet glass concentrator has the ability to resist atomic oxygen and the glass can be cleaned easily without scratching. These characteristics make a microsheet concentrator extremely desirable for orbital and lunar applications.

A method was also developed to coat mill finished aluminum surfaces with a polymer leveling coating producing a surface with an high quality optical surface. The procedures were defined to clean and coat an aluminum surface with Eccocoat EP-3 epoxy.

Future plans of the ASD concentrator program include identifying a space qualified coating, with similar properties to Eccocoat EP-3. Currently DC 93-500 is being investigated as a potential candidate. Alternative coating methods such as spin coating are also being investigated as part of the ASD Concentrator effort.

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